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BRIEFER ARTICLES

CONCAVITY OF LEAVES AND ILLUMINATION

(WITH ONE FIGURE)

Concavity of the upper surfaces of leaves is of extremely common occurrence among the higher plants. WIESNER, in an important paper,[1] has discussed this concave upper leaf surface as a characteristic of the peripheral leaves of woody plants, and states that the leaves within the shadow of the crown of trees (with concave outer leaves) are generally flat or nearly so. He classes these and other leaves which are capable of some kind of temporary or permanent adjustment to the amount of light received as panphotometric leaves, regarding the concavity as useful in preventing injury to chlorophyll by excessive sunlight. OLTMANNS[2] calls attention to the fact that the leaflets of *Robinia Pseudo-Acacia* are concave on the south sides of trees, but flat on the north sides.

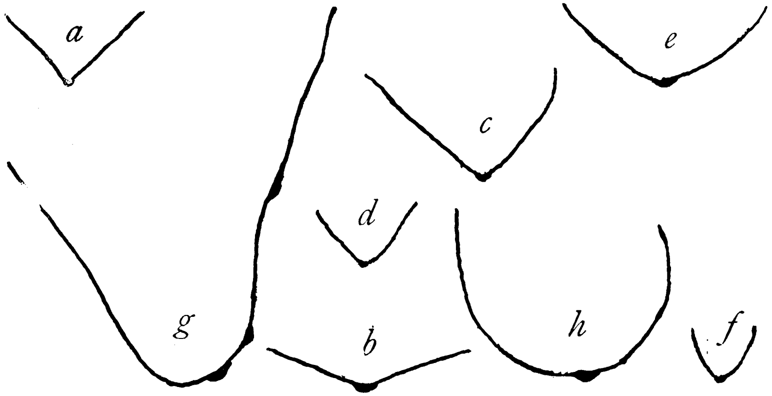

FIG. 1.—Diagram of cross-sections of leaves, taken at right angles to the midrib (if there is any) and through its middle point. $\times\frac{4}{5}$. *a*, Astilbe decandra; *b*, Prunus persica; *c*, Syringa vulgaris; *d*, Akebia quinata; *e*, Citrus medica; *f*, Styrax japonica; *g*, Begonia semperflorens; *h*, Schizophragma hydrangeoides.

It seemed to the writer worth while to make some notes as to the occurrence of the concavity in question among various genera, particularly among trees and shrubs, and to take a few measurements of the amount of concavity in shaded and unshaded leaves of the same individual. Most of the species observed were growing in the Botanic Garden of Harvard University. No attempt was made to pick out particular families for examination, but notes were made on any leaves, especially of dicotyledonous trees or shrubs, that showed decided concavity of the upper surface. Some slight amount of deviation from flatness seemed almost universal. The observations were made on mature vigorous leaves during the first week in September.

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[1] WIESNER, J., Anpassung des Laubblattes an die Lichtstärke. Biol. Centralbl. 1–15. 1899.

[2] OLTMANNS, F., Photometrische Bewegungen der Pflanzen. Flora 79:232, 233. 1892.

The leaves or leaflets examined in many instances showed a rather definite dihedral angle, as in *a* and *b*, *fig. 1.* More often the surfaces on each side of the midrib were decidedly curved, as in the cases *c–f*, while some leaves, as in *g* and *h*, showed no semblance of an angle in the cross-section, but formed a rather deep trough, with curved sides.

Measurements of angles were made by means of two straight-edged pieces of brass, hinged at one end and applied outside the leaf or leaflet at right angles to the midrib. In case the leaf surfaces were somewhat convex beneath, the angle taken was that subtended by a tangent to the middle points of the halves of the leaf.

Plants of 31 families of dicotyledons, comprising 52 genera and possibly 200 species, were noted as showing decided concavity of the upper surfaces of the leaves. Little attempt was made to find out how generally marked leaf-concavity characterized the various species of the genera examined. In some instances, e. g., Viburnum, it occurred in almost all the species accessible for observation, while in other cases, e. g., Magnolia, Acer, it was present in some species and absent in others.

The following measurements of dihedral leaf angles or concavities were obtained:

Species	Angle in degrees, sunlight	Angle in degrees, shade
Akebia quinata (leaflets)	106	167–180*
Magnolia acuminata	80–180	180 or recurved
Astilbe decandra (leaflets)	80–153	180 or recurved (167)
Hydrangea quercifolia	134–180	180 or less
Schizophragma hydrangeoides	28–180	180 or less
Fothergilla Gardeni	80–180	180 or less
Robinia Pseudo-Acacia (leaflets)	90–137	180*
Begonia semperflorens	23–56	108–180
Aralia pentaphylla (leaflets)	often semicircular	180
Ligustrum Ibota	54–145	180
Syringa vulgaris	55–145	130–180
Cephalanthus occidentalis	102–153	180
Viburnum nudum	83–105	180

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* The shade leaves were all measured from the densest shade afforded by the foliage of the plant itself. In the two cases marked by an asterisk the leaves were also in the shade of other trees or a wall.

It is undoubtedly a fact that the great majority of woody dicotyledons have leaves which when freely exposed to the sun are concave on the upper surface and that this concavity usually lessens or disappears in the case of much-shaded leaves on the same plant. WIESNER's conclusion that this conformation is due to the effects of powerful illumination seems on the whole to be plausible. It is not safe, however, to assume, as he does, that we have here an undoubted case of protective adaptation, to ward off the injurious effect upon chlorophyll of excessive insolation. In order to prove this it would be necessary to explain many real or apparent exceptions to the assumption that greater concavity should go with greater illumination. To cite the first instances that occur: *Acer Negundo* is hardly, if at all, more exposed to excessive sunlight in its usual habitats than is *A. saccharinum*, and yet the former has trough-like leaflets, while the leaves of the latter are nearly flat. The Japanese *Ligustrum Ibota* comes from a region not enough more subject to excessive sunlight than that of the European *L. vulgare* to account for the great difference in the flatness of the leaves of the two species. *Vinca rosea*, a West Indian weed, might be expected to have leaves much more concave than those of the European *V. minor*, but the reverse is actually the case. Occasionally leaves growing in shade may be decidedly more concave than those growing under greater illumination, as I have noted in one case of *Kalmia angustifolia*. Finally, it is difficult to explain on any theory of utility of concave leaf surfaces in protecting chlorophyll the fact that the angular values obtained for leaves of the same individual, grown under similar conditions, vary so much. The angles given in the preceding table for each species were in many instances obtained from leaves which apparently received almost identical illumination, since they grew fairly near together and were sometimes almost in contact with each other. Yet, as will be observed, the angles for sun leaves sometimes varied in a ratio as high as six to one. Equally difficult to explain is the fact that in some genera, e. g., Prunus, Pyrus, Salix, the whole tree may show little difference in the flatness of the leaves, all being angled whether they grow in sun or shade.

Instead of trying, as WIESNER has done, to establish the critical intensity of illumination at which leaves of a given species cease to be panphotometric and become euphotometric, it would seem to the writer better worth while to look for some relation (always on the same individual) between illumination and the average amount of angular divergence of the halves of the leaf, basing all statements on a large number of measurements.—JOSEPH Y. BERGEN, *Cambridge, Mass.*